U.S.D.A. Forest Service
Research Paper RM-47

1969

Major Insect Pests in North Dakota Shelterbelts:

Abundance and Distribution by Climate and Host Age

Patrick C. Kennedy and Louis F. Wilson

Rocky Mountain Forest and Range Experiment Station
Forest Service U. S. Department of Agriculture
Fort Collins, Colorado 80521

U.S.D.A. Forest Service
Research Paper RM-47

1969

MAJOR INSECT PESTS IN NORTH DAKOTA SHELTERBELTS:

Abundance and Distribution by Climate and Host Age[1]

by

Patrick C. Kennedy, Associate Insect Ecologist[2]

and

Louis F. Wilson, Principal Insect Ecologist[2]

[1]Research reported here was conducted at the Shelterbelt Laboratory, Bottineau, in cooperation with North Dakota School of Forestry. The Shelterbelt Laboratory, formerly a part of North Central Forest Experiment Station, is now a project location for the Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained at Fort Collins, in cooperation with Colorado State University.

[2]North Central Forest Experiment Station, East Lansing, Michigan, with central headquarters at St. Paul, Minnesota.

CONTENTS

Major Insect Pests in North Dakota Shelterbelts:

Abundance and Distribution by Climate and Host Age

Patrick C. Kennedy and Louis F. Wilson

Introduction

Shelterbelts consist of one or more rows of living trees and shrubs whose function is to reduce wind velocity, evaporation, and wind erosion. They also protect crops, control snowdrifting, and furnish cover and food for wildlife. More recently they have been planted for highway beautification and shade for rest areas.

North Dakota leads the other Great Plains States in the number of trees (over 276,433,000) and acres (over 329,800) planted. Tree planting efforts were stepped up from 1916 to 1933; and between 1935 and 1942 a very intensive shelterbelt planting program was carried out under the Prairie States Forestry Project. Large-scale planting has continued today in North Dakota, with about 8,000 acres planted annually.

Insect investigations in Great Plains shelterbelts were begun about the same time as the Prairie States Forestry Project. Most investigations have been concerned with cataloging shelterbelt pests or describing their damage.[2] Wilson (1962) conducted an extensive survey of the forest insects and diseases in the Northern Great Plains, and discussed the kinds of pests and their damage in eastern North Dakota shelterbelts. Ewan[3] compiled a list of 119 potentially important insect species found in Great Plains shelterbelts.

A more intensive study, reported here, was carried out from 1963 to 1965 to find out which insects were currently or potentially important to North Dakota shelterbelts, and to determine if their distribution and abundance were influenced by climate and host age.

Methods

The study was conducted during the summers of 1963 to 1965. In 1963, 107 multirow shelterbelts were selected in three age classes and six climatic zones throughout North Dakota (figs. 1, 2). Concurrently, insect and damage data were collected. The same belts were revisited and intensively sampled for insects and damage in 1964. Selected belts were visited a third time in 1965 to collect and identify insects whose damage had been classified as unknown the previous year.

Climatic Zones

Long-term rainfall and temperature data were used to partition North Dakota into climatic zones before field data were collected. January temperatures average -2° F. in the northeast and 14° F. in the southwest. The average precipitation during the warm season varies from slightly more than 16 inches in the southeast to less than 10 inches in the northwest (Bavendick 1941). The January isotherm at 6° F. was selected because it conveniently bisected the State from northwest to southeast. Isohyets at 12 inches and 14 inches likewise divided the State into thirds. The State was thus divided into six zones with the following characteristics: (1) cold, moist; (2) warm, moist; (3) cold, dry; (4) warm, dry; (5) cold, very dry; and (6) warm, very dry (fig. 1). At least 17 belts were selected in each climatic zone; zones 4 and 6 had 19 and 20 belts, respectively.

Shelterbelt Age

Sample shelterbelts ranged in age from 5 to over 50 years. Microclimatic differences in different-aged belts should affect insect distribution and abundance. Three age classes—I, 5-15 years; II, 16-25 years; and III, 26 years or older—were studied. At least seven shelterbelts per zone were examined in age classes I and II, but only three belts in age class III were examined per zone because of a shortage of suitable belts.

Insect Prevalence

A prevalence index was devised to compare the relative numbers of any one species of insect from place to place, and to compare at least roughly the significance or impact of one insect population of the same or different species on one or more hosts. Host damage data

[2]*Munns and Stoeckeler 1946; Munro 1939; Read 1964; Wilson 1961, 1962; Wygant 1938.*

[3]*Ewan, H. G. The northern Great Plains, a problem selection. 1962. (Typewritten report, Lake States Forest Exp. Sta., on file at North Central Forest Exp. Sta., St. Paul, Minn.)*

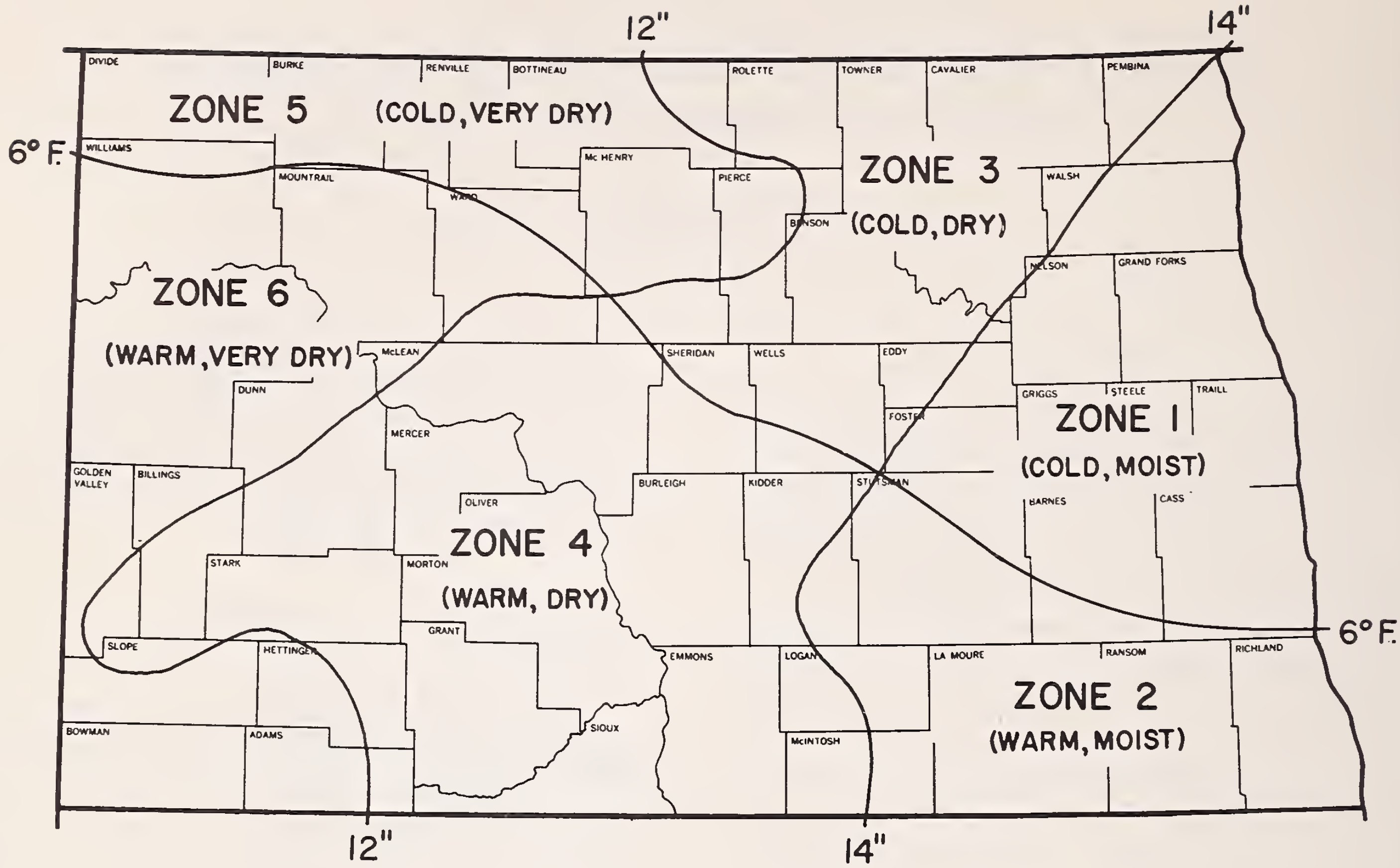


Figure 1.--Division of the State of North Dakota into climatic zones.

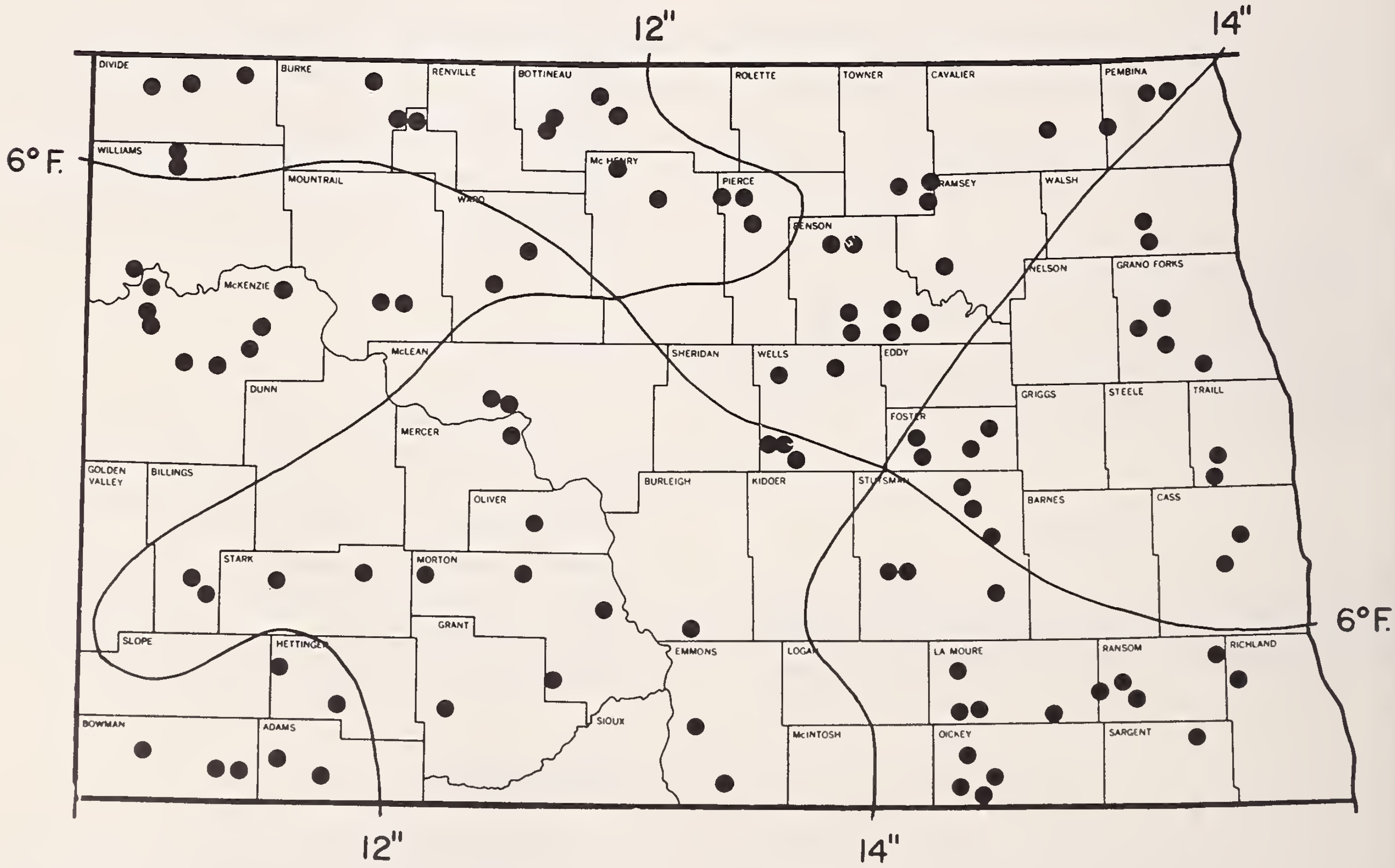


Figure 2.--Location of the 107 shelterbelts examined in the study.

rather than actual insect numbers were almost always used in the index. Some insects, such as borers, were difficult to observe directly. Others, such as defoliators, were present in the feeding stages for only a relatively short period and thus impossible to observe continuously. Representative insects were collected as needed to determine the cause of damage.

An estimate of the degree of damage to the individual host tree or shrub and the percentage of hosts infested were combined to calculate the prevalence index for each insect in each belt. First, four degrees of damage were recognized on individual trees:

Host Symptom	Damage to individual host (numerical value)
Tree unaffected, or insects and damage scarce and difficult to detect.	0
Insect or damage present but less than 5 percent defoliation; leaves affected, or twig tips affected.	1
Noticeable damage but less than one-fourth of the tree crown affected.	2
More than one-fourth of the crown affected, or any evidence of a primary boring insect in the trunk or large branches.	4

Second, the numerical value of the individual host was multiplied by the percentage of hosts so affected. For example, suppose 10 green ash trees were inspected for the fall cankerworm; 2 had suffered a trace of defoliation, 1 suffered heavy defoliation, and the other 7 were apparently free from damage. The prevalence index for the fall cankerworm on green ash in this belt would be:

Damage to individual host (numerical value)	Trees affected (percent)	Numerical value X percent
0 (unaffected)	70	0
1 (trace)	20	20
2 (light-moderate)	0	0
4 (heavy)	10	40
	Prevalence index =	60

In this manner, prevalence indices were calculated for each insect on each host in each belt. In addition, mean prevalence indices were calculated from belt indices for each insect by climatic zone, the entire State, and host age class. Each index has a range from 0 (no trees or belts affected) to 400 (all trees or belts heavy).

Sampling

In 1963, 16 to 36 systematically selected trees were examined per belt. In 1964, sampling was done in June and early July for early-season insects, and mid-July to late August for late-season insects. All belts were sampled once; all but five were sampled twice. At least 12 systematically selected trees or shrubs of each species were examined in each belt unless the species was very scarce.

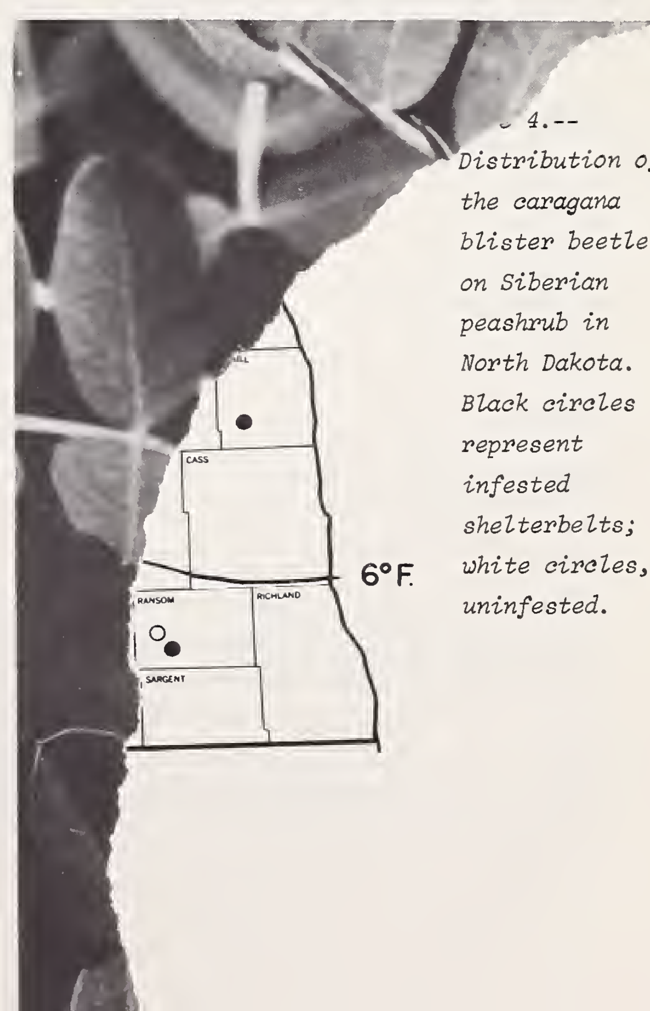
Abundance and Distribution

Over 30 species of insects and mites were collected from 23 species of trees and shrubs. The hosts are listed in table 1. The 16 most frequently encountered species (or species groups) of insects listed in table 2, were collected from seven of the top eight hosts listed in table 1. No insects were found during this study onRussian-olive, however, which was the fifth most prevalent tree.

Abundance and distribution of the most important pests are discussed below in order of their prevalence. Statewide and local infestation levels (in terms of light, moderate, heavy) are suggested for some of them because prevalence indices alone are difficult to compare directly between insect species. Potentially destructive insects collected but not listed in the tables are briefly discussed also.

Caragana blister beetle

Adult caragana blister beetles defoliate Siberian peashrub (caragana) and occasionally other hosts in early summer (fig. 3). The Statewide prevalence index of 144, based on adult beetle defoliation measured after or late



4.--Distribution of the caragana blister beetle on Siberian peashrub in North Dakota. Black circles represent infested shelterbelts; white circles, uninfested.

Figure 3.--Caragana blister beetle adults feeding on the leaves and seedpods of Siberian peashrub. (FS 500803)

Table 3.--Mean prevalence index by climatic zones for the five most frequently encountered shelterbelt insects in North Dakota during 1964 (all host age classes are combined)

Insect	Host	Mean prevalence index by climatic zones					
		Cold, moist (1)	Warm, moist (2)	Cold, dry (3)	Warm, dry (4)	Cold, very dry (5)	Warm, very dry (6)
Caragana blister beetle	Siberian peashrub	82	156	89	174	57	243
Woolly elm aphid	American elm	84	110	76	73	139	79
Boxelder twig borer	boxelder	71	110	73	71	82	31
Poplar petiole gall aphid	eastern cottonwood	47	131	61	72	70	27
Fall cankerworm	boxelder	107	27	113	32	126	102
	American elm	176	34	75	47	82	14
	green ash	114	18	62	15	67	51
	Siberian elm	76	10	62	27	58	7
	All cankerworm hosts combined	124	22	76	29	88	34

Table 4.--Mean prevalence index by shelterbelt age classes and climatic zones for the five most common insects in North Dakota shelterbelts in 1964

Insect and shelterbelt age class	Mean prevalence index by climatic zones						
	Cold, moist (1)	Warm, moist (2)	Cold, dry (3)	Warm, dry (4)	Cold, very dry (5)	Warm, very dry (6)	All zones
Caragana blister beetle							
I (5-15 years)	58	242	154	165	64	253	165
II (16-25 years)	114	71	38	217	35	241	111
III (26 years and older)	58	--	150	--	108	200	144
Woolly elm aphid							
I	98	110	54	51	149	85	92
II	77	97	85	104	119	80	89
III	83	167	75	109	--	50	95
Boxelder twig borer							
I	71	67	79	75	132	9	79
II	71	125	77	70	53	108	77
III	--	--	58	58	54	0	44
Poplar petiole gall aphid							
I	26	146	35	117	--	0	62
II	48	81	70	83	72	54	64
III	83	197	91	0	108	133	109
Fall cankerworm (all hosts)							
I	110	29	24	17	52	18	38
II	135	19	69	67	97	83	84
III	111	0	167	24	165	0	83

Woolly elm aphid

Colonies of woolly elm aphids cause the leaves to curl (fig. 5) and perhaps cause early leaf-fall from American elm—this insect's only known host. The Statewide prevalence index in 1964 was 91 based on the amount of leaf-curl (table 2)—heavier than the 1960 findings (Wilson 1962). As leaf-curl was not as severe as defoliation in 1964, the Statewide infestation was considered light. Individual trees in certain belts were heavily attacked and may have been weakened.

Woolly elm aphid damage was observed in 66 out of 68 belts containing American elm. It was well represented in all climatic zones (fig. 6), but somewhat more prevalent in zones 2 and 5 (table 3). All age classes were attacked about equally, but there was considerable inconsistency by individual zones (table 4).

Figure 5.--Woolly elm aphids and damage to American elm leaf. Note the lady bird beetle (Coleoptera-Coccinellidae) feeding upon the aphids. (FS 500798)

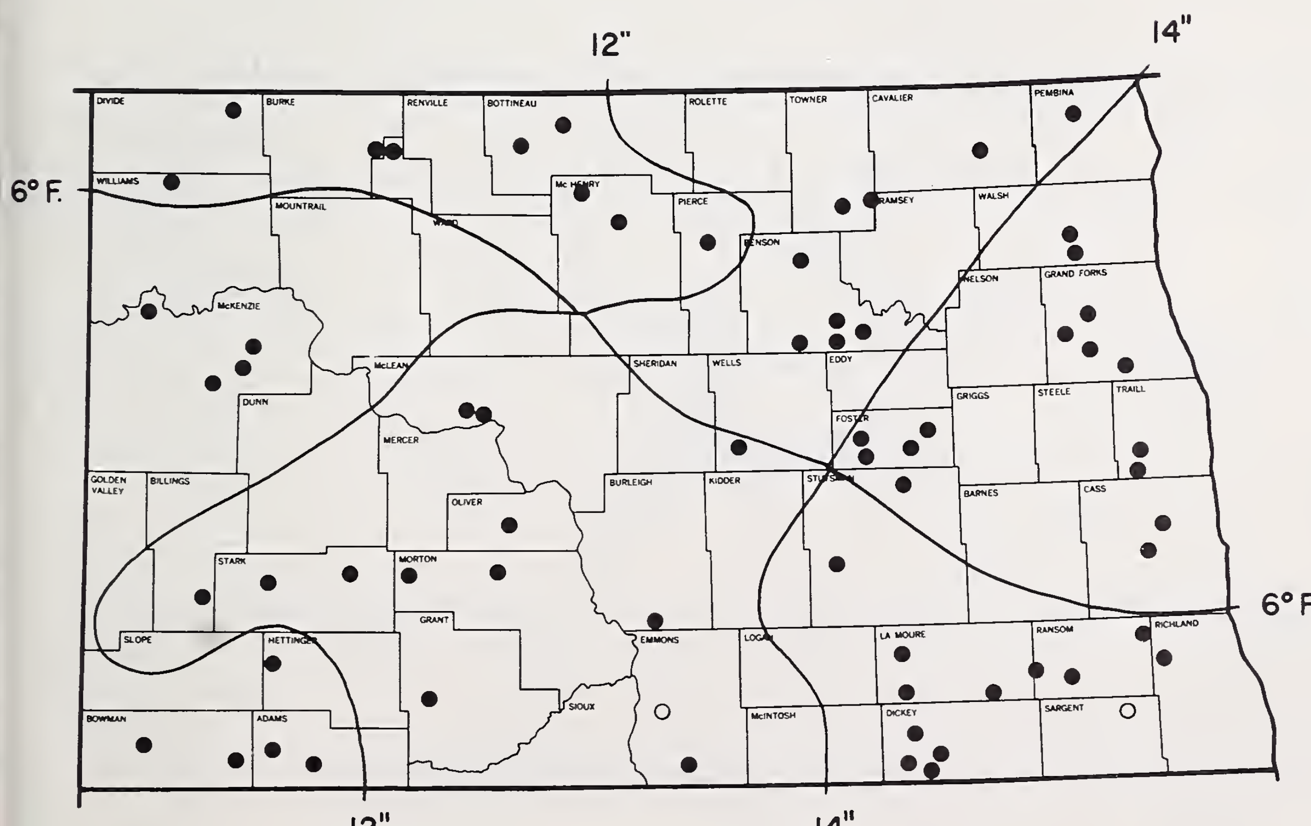


Figure 6.--Distribution of the woolly elm aphid on American elm in North Dakota.

Table 3.--Mean prevalence index by climatic zones for the five most frequently encountered shelterbelt insects in North Dakota during 1964 (all host age classes are combined)

Insect	Host	Mean prevalence index by climatic zones					
		Cold, moist (1)	Warm, moist (2)	Cold, dry (3)	Warm, dry (4)	Cold, very dry (5)	Warm, very dr (6)
Caragana blister beetle	Siberian peashrub	82	156	89	174	57	243
Woolly elm aphid	American elm	84	110	76	73	139	79
Boxelder twig borer	boxelder	71	110	73	71	82	31
Poplar petiole gall aphid	eastern cottonwood	47	131	61	72	70	27
Fall cankerworm	boxelder	107	27	113	32	126	102
	American elm	176	34	75	47	82	14
	green ash	114	18	62	15	67	51
	Siberian elm	76	10	62	27	58	7
	All cankerworm hosts combined	124	22	76	29	88	34

Table 4.--Mean prevalence index by shelterbelt age classes and climatic zones for the five most common insects in North Dakota shelterbelts in 1964

Insect and shelterbelt age class	Mean prevalence index by climatic zones						
	Cold, moist (1)	Warm, moist (2)	Cold, dry (3)	Warm, dry (4)	Cold, very dry (5)	Warm, very dry (6)	All zones
Caragana blister beetle							
I (5-15 years)	58	242	154	165	64	253	165
II (16-25 years)	114	71	38	217	35	241	111
III (26 years and older)	58	--	150	--	108	200	144
Woolly elm aphid							
I	98	110	54	51	149	85	92
II	77	97	85	104	119	80	89
III	83	167	75	109	--	50	95
Boxelder twig borer							
I	71	67	79	75	132	9	79
II	71	125	77	70	53	108	77
III	--	--	58	58	54	0	44
Poplar petiole gall aphid							
I	26	146	35	117	--	0	62
II	48	81	70	83	72	54	64
III	83	197	91	0	108	133	109
Fall cankerworm (all hosts)							
I	110	29	24	17	52	18	38
II	135	19	69	67	97	83	84
III	111	0	167	24	165	0	83

/oolly elm aphid

Colonies of woolly elm aphids cause the leaves to ɹrl (fig. 5) and perhaps cause early leaf-fall from Ameri- ɔan elm—this insect's only known host. The Statewide revalence index in 1964 was 91 based on the amount f leaf-curl (table 2)—heavier than the 1960 findings (Wil- ɔn 1962). As leaf-curl was not as severe as defoliation ı 1964, the Statewide infestation was considered light. ıdividual trees in certain belts were heavily attacked and ıay have been weakened.

Woolly elm aphid damage was observed in 66 out f 68 belts containing American elm. It was well repre- ented in all climatic zones (fig. 6), but somewhat more revalent in zones 2 and 5 (table 3). All age classes /ere attacked about equally, but there was considerable ıconsistency by individual zones (table 4).

Figure 5.--Woolly elm aphids and damage to American elm leaf. Note the lady bird beetle (Coleoptera-Coccinellidae) feeding upon the aphids. (FS 500798)

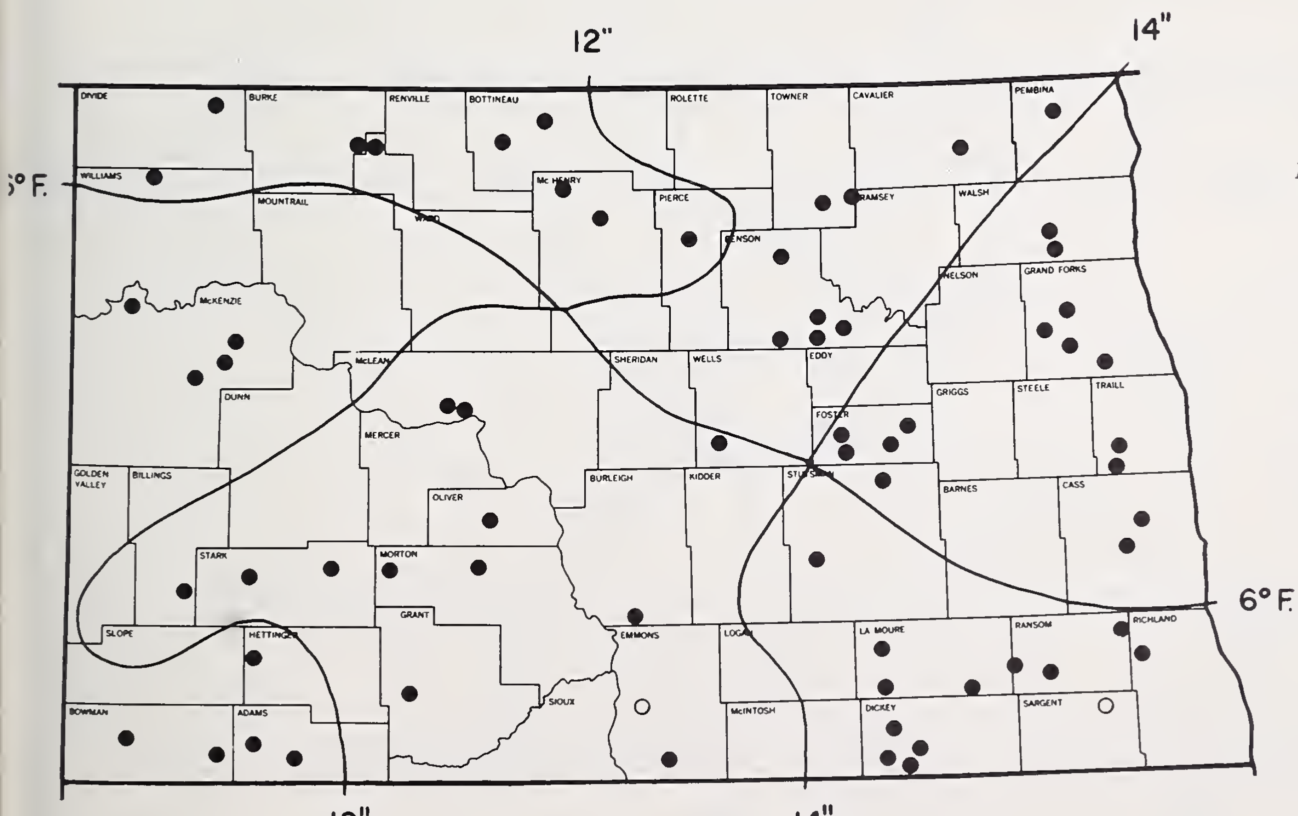


Figure 6.--Distribution of the woolly elm aphid on American elm in North Dakota.

Boxelder twig borer

The larvae of this insect (fig. 7) destroy dormant leaf buds in early May, then burrow into and kill developing shoots in late May (Peterson 1958, 1964). The swollen and injured shoots can be detected for most of the summer.

Statewide prevalence index for the boxelder twig borer was 74, based on infested branch tips (table 2). Considering that each larva destroys an entire growing shoot, the Statewide infestation was interpreted as light to moderate. Only one belt had a prevalence index over 200.

This boring insect was represented in 42 out of 44 belts containing boxelder, and in all climatic zones; boxelder was poorly represented in the southern half of the State, however (fig. 8). The warm, very dry climatic zone 6 had the two uninfested belts and showed the lowest prevalence index (table 3). Climatic zone 2 had a slightly higher than average prevalence index. Trees in age classes I and II appeared to be injured slightly more than those in age class III, but detecting and estimating the infestation on large trees was difficult.

Figure 7.--Boxelder twig borer larva and tunnel in young boxelder shoot. (FS 500805)

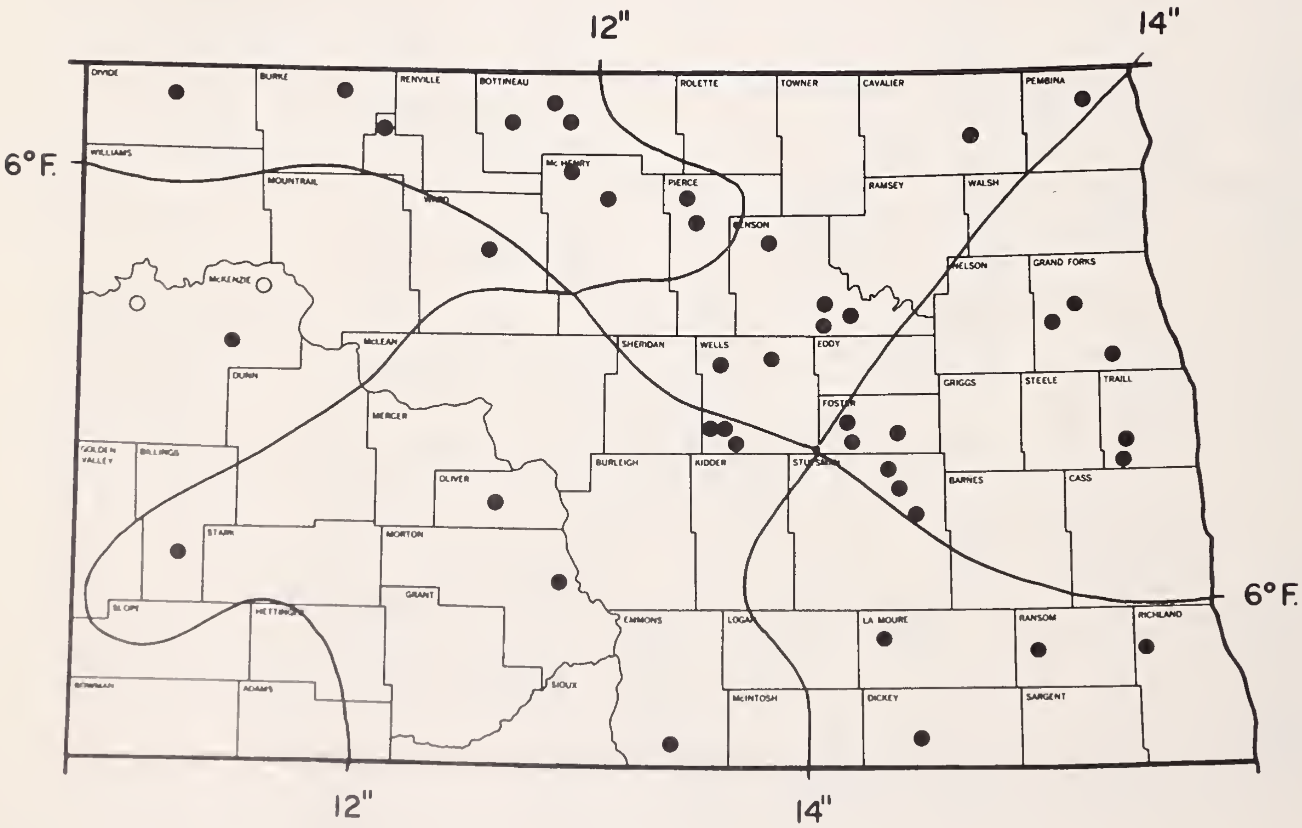


Figure 8.--Distribution of the boxelder twig borer on boxelder in North Dakota.

Poplar petiole gall aphid

This insect makes a single globular gall on the leaf petioles of trees in the genus Populus which is represented primarily by eastern cottonwood in North Dakota shelterbelts(fig. 9). The Statewide prevalence index for the insect was 73, based on galled cottonwood leaves. Considering the minor damage this insect causes, the Statewide infestation was interpreted as very light to light.

Both cottonwood and the insect were poorly represented in the southern portion of the State (fig. 10). All belts were infested in the warm, moist zone 2, which also had the highest prevalence index (table 3). In general, class III trees were attacked slightly more than the younger trees, but this was inconsistent by zones (table 4).

Figure 9.--Poplar petiole gall aphid damage on cottonwood leaf. (FS 518112)

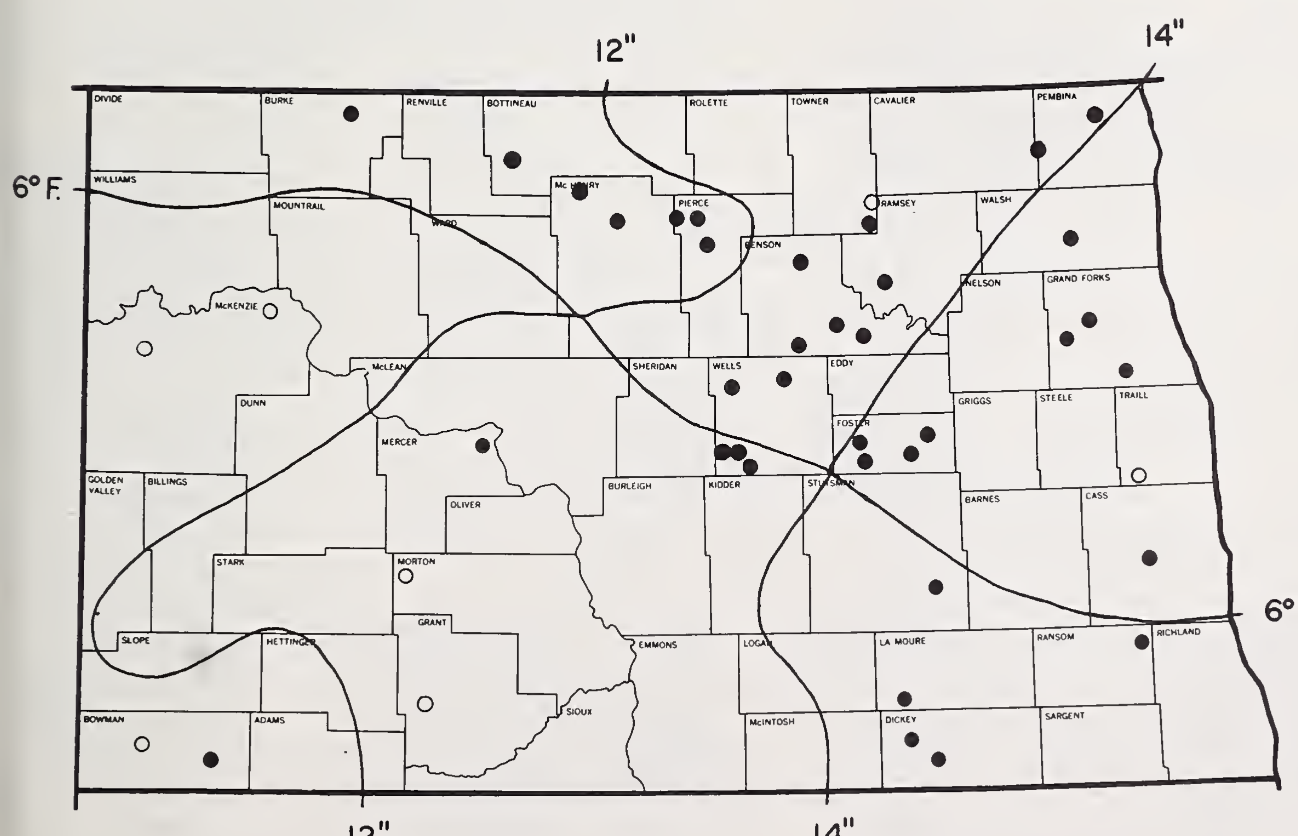


Figure 10.--Distribution of the poplar petiole gall aphid on eastern cottonwood in North Dakota.

Fall cankerworm

The larvae of the fall cankerworm usually feed until mid-June in North Dakota. They are general-feeding defoliators (fig. 11) on several kinds of shelterbelt trees, but especially on boxelder, American elm, green ash, and Siberian elm. A few larvae were also collected from Siberian peashrub, eastern cottonwood, and chokecherry. These may have been spurious insects. In one instance, cankerworm larvae started feeding on spruce needles after their normal hosts were defoliated.

The overall Statewide prevalence index for the four primary hosts combined was 62, based on amount of defoliation after the feeding period (table 2). The Statewide prevalence indices for individual hosts in order of preference were: boxelder 94, American elm 75, green ash 67, and Siberian elm 37. Siberian elm was somewhat less susceptible to attack than the others, even when the other hosts were present with Siberian elm.

At least 1 of the 4 species of trees was represented in each of the 107 shelterbelts examined, but only 53 belts were infested by the fall cankerworm (fig. 12). The prevalence index was high in the northern part of the

Figure 11.--Fall cankerworm larvae feeding on American elm leaf. (FS 518111)

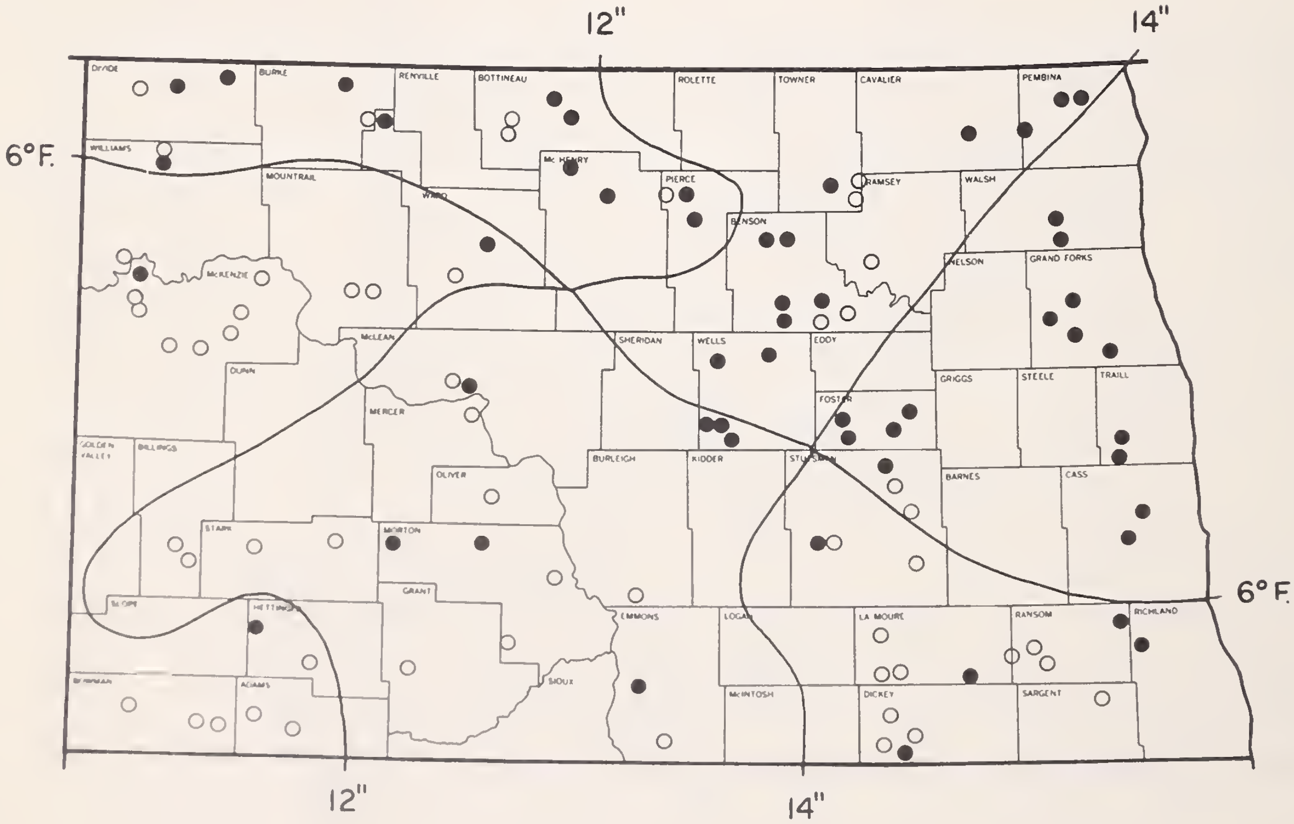


Figure 12.--Distribution o the fall canker on boxelder, American elm, green ash, and Siberian elm in North Dakot

State (climatic zones 1, 3, 5; table 3), particularly in the cold, moist zone 1. Only 27 percent of the southern belts were infested in contrast to 75 percent of the northern belts. Age class II and III trees sustained heavier attacks in most zones, and those in age class III sustained the heaviest attacks in the northern zones (3, 5; table 4).

Grasshoppers

The Statewide prevalence index for grasshoppers was 31, based on defoliation and debarking of Siberian peashrub and Tatarian honeysuckle (table 2). Although this index suggests a very light infestation in 1964, most grasshopper damage occurs late in the summer following harvesting (Wilson 1961), and the study was nearly completed by then. Of 67 shelterbelts with Siberian peashrub, honeysuckle, or both, 16 were attacked by grasshoppers. Nine of these were in the very dry western climatic zones (5, 6) where several had very high prevalence indices. In contrast, infested belts in the other zones were lightly attacked. Trees in age class I were the most heavily damaged.

Although Siberian peashrub and Tatarian honeysuckle were the only shrubs attacked by grasshoppers, most other species of trees and shrubs are susceptible to attack—especially in dry years (Wygant 1938). In the past, young shelterbelts containing several species of trees and shrubs, including ponderosa pine, have been completely denuded by grasshopper invasions (George 1953, Munns and Stoeckeler 1946, Severin 1948).

Other pests

The other pests encountered in this study were not abundant or injurious except in local areas. Of those listed in table 2, only the fall webworm caused noticeable damage. It was collected in nine locations, mostly in zone 4, on American plum and chokecherry. Scattered trees were attacked, but because all the belts with the insect were young (5 to 12 years old), a few trees were heavily defoliated. Galls of the poplar vagabond aphid were abundant on a few scattered cottonwood trees in 10 belts throughout the State.

Other potentially destructive pests—not listed in table 2—which caused only a trace of damage were: hornworms (*Sphinx* spp.), ash borers, probably the carpenterworm (*Prionoxystus robiniae* (Peck)), elm lace bug (*Corythucha ulmi* O.&D.), mourning-cloak butterfly (*Nymphalis antiopa* (L.)), pine needle scale (*Phenacaspis pinifoliae* (Fitch)), and chrysomelid beetles (species unknown). The hornworms were collected on ash, honeysuckle, and cotoneaster in zones 4 and 6.

Discussion

Six kinds of insects were injurious to six of the seven most prevalent species of trees and shrubs. In order of prevalence they were: caragana blister beetle, woolly elm aphid, boxelder twig borer, poplar petiole gall aphid, fall cankerworm, and spur-throated grasshoppers. All except the fall cankerworm were also considered the most injurious insects in Northern Great Plains shelterbelts in 1960 (Wilson 1962). The fall cankerworm may have been more abundant then, too, than was realized.

The six primary hosts attacked by these pests in order of frequency of occurrence were: green ash, American elm, Siberian elm, Siberian peashrub, boxelder, and eastern cottonwood. Russian-olive also occurred frequently, but was almost entirely free from insects. Wilson (1962) found the same six hosts led the list for pest injury in the Northern Great Plains, and that Russian-olive was uninjured also. The insect situation will probably become more acute because insect-susceptible tree and shrub species are still being planted extensively. Russian-olive is being planted less and less because of its short life expectancy, and its susceptibility to diseases.

A few of the less frequently encountered trees and shrubs were also attacked by the primary insects that are polyphagus. Tatarian honeysuckle was occasionally injured by grasshoppers; American plum and chokecherry were infrequently attacked by the fall webworm. Other trees and shrubs were relatively free from insect attacks.

The fall cankerworm was perhaps the most serious of the six primary insects because it damaged boxelder, American elm, green ash, and Siberian elm. No other insect injured so many hosts. Although it is capable of widespread and severe defoliation, wide population fluctuations have kept damage from becoming excessive. The population was probably light in North Dakota shelterbelts in 1960, and was moderate in this study during 1963 and 1964.

The next most serious problem insects occurred on Siberian peashrub, particularly in the southwestern portion of the State. These were the caragana blister beetle and spur-throated grasshoppers. The larvae of blister beetles prey on grasshopper eggs, which may partly account for their higher populations in southwestern North Dakota where grasshoppers were also abundant. Grasshoppers were undoubtedly underrated in this study; they may be much more serious pests, especially in dry years.

Adult blister beetles feed early and may partially or completely defoliate Siberian peashrubs, while grasshoppers feed late and may remove the remaining foliage and much of the bark. Munns and Stoeckeler (1946) remarked that blister beetles were especially harmful when heavy grasshopper and blister beetle populations occurred together in successive years. Although the blister beetles usually attack just caragana, grasshoppers attack all edgerow species because these shrubs are the first plants available to them following depletion or harvesting of their

normal hosts (Wilson 1961). Other insects occasionally attack caragana (Kennedy 1968) but none of them were important in 1964.

The boxelder twig borer was perhaps the next most important pest. Abundant in some localities, it damaged boxelder along with the fall cankerworm, which preferred boxelder slightly over the other hosts.

The woolly elm aphid was next most important because of its prevalence. It probably is less injurious than the defoliators and twig borer, because of its leaf-curling habits, although its attacks certainly weaken the tree. It could be very important when abundant on American elms that are also heavily attacked by the fall cankerworm. The poplar petiole gall aphid was abundant on eastern cottonwood, but its presence in the petiole appears to cause little damage.

Records of all known and unclassified defoliation combined suggested a rough trend of increasing injury from the eastern zones to the western zones in 1963. The 1964 data which were more reliable, showed slightly more injury in the western zones, but no differences in the central and eastern zones. Blister beetle and grasshopper feeding contributed heavily to the trends.

Although overall insect injury in the northern and southern zones did not differ, most injury in the south was caused by the caragana blister beetle; in the north by the fall cankerworm. These distributions suggest differential tolerance due to climate. The damage caused by the woolly elm aphid was more cosmopolitan. Injury from the boxelder twig borer and the poplar petiole gall aphid was somewhat more common in the northern part of the State, but mainly because their hosts were also better represented there.

There was little consistency among prevalence indices by age classes and climatic zones for any insect. In all instances age class III trees were far too few to give reliable information. The fall cankerworm appeared to be slightly more injurious to age class II trees. Other defoliators generally caused more injury to age class I trees and shrubs. Blister beetles were sufficiently abundant in some areas, however, to cause severe injury to caragana of all age and size classes.

Belts under 5 years old, which were not examined in this study, should be examined in the future because they are least tolerant to insect attacks. Low population levels of defoliators such as blister beetles, grasshoppers, and large caterpillars can easily destroy young trees and shrubs. Wilson (1962) reported heavy defoliation of caragana by blister beetles in a nursery. He also found young green ash trees completely stripped by larvae of the great ash sphinx (Sphinx chersis Hübner).

The major insects discussed, except the poplar petiole gall aphid, are potentially destructive over broad regions of North Dakota. Deficient rainfall, temperature extremes, desiccating winds, and unfavorable soil conditions stress shelterbelt trees, and contribute to their decline. Even low insect populations could hasten deterioration of trees under stress.

Literature Cited

Bavendick, Frank J.
1941. Climate of North Dakota. U. S. Dep. Agr. Yearb. 1941: 1045-1054.

Brown, C. E.
1955. A study of the factors influencing population fluctuations in the fall cankerworm.* Interim Rep. 1953, 25 pp. Can. Dep. Agr. Forest Biol. Lab.

George, E. J.
1953. 31-year results in growing shelterbelts on the northern Great Plains. U. S. Dep. Agr. Circ. 924, 57 pp., illus.

Kennedy, Patrick C.
1968. Insects and diseases of Siberian peashrub (caragana) in North Dakota and their control.* U. S. Forest Serv. Res. Note RM-104, 4 pp., illus. Rocky Mountain Forest and Range Exp. Sta., Fort Collins, Colo.

Munns, Edward N., and Stoeckeler, Joseph H.
1946. How are the Great Plains shelterbelts? J. Forest. 44: 237-257.

Munro, J. A..
1939. The insect problem in shelterbelt plantations. N. Dak. Agr. Exp. Bimon. Bull. 1(6): 3-4.

Peterson, L. O. T.
1958. The boxelder twig borer, Proteoteras willingana (Kearfoot), (Lepidoptera: Olethreutidae). Can. Entomol. 60: 639-646.

———
1964. The boxelder twig borer.* Can. Dep. Agr. TN-1, 6 pp., illus.

Read, Ralph A.
1964. Tree windbreaks for the central Great Plains. U. S. Dep. Agr. Agr. Handb. 250, 68 pp., illus.

Severin, H. C.
1958. Shelterbelt investigations. In Agr. Res. in S. Dak., 61st Annu. Sta. Rep., July 1, 1947-June 30, 1948, pp. 21-23. S. Dak. Agr. Coll. and Exp. Sta., Brookings, S. Dak.

Wilson, L. F.
1961. Grasshoppers—a major defoliator of trees and shrubs in the northern Great Plains.* U. S. D. A. Forest Serv., Lake States Forest Exp. Sta. Tech. Note 596, 2 pp., illus. St. Paul, Minn.

———
1962. Forest insects and diseases in the northern Great Plains—a survey.* U.S.D.A. Forest Serv., Lake States Forest Exp. Sta. Sta. Pap. 101, 28 pp., illus. St. Paul, Minn.

Wygant, N. D.
1938. The relation of insects to shelterbelt plantations in the Great Plains. J. Forest. 36: 1011-1018.

*Address requests for copies to originating office.

Agriculture --- CSU, Ft. Collins

Kennedy, Patrick C., and Wilson, Louis F.
1969. Major insect pests in North Dakota shelterbelts: abundance and distribution by climate and host age. U.S.D.A. Forest Service Research Paper RM-47, 12 pp., illus. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado 80521.

Over 30 species of insects and mites were found on 23 species of trees and shrubs. A prevalence index was devised to compare relative numbers of insects and their impact on hosts. The caragana blister beetle, woolly elm aphid, boxelder twig borer, poplar petiole gall aphid, fall cankerworm, and spur-throated grasshopper had highest prevalence indices. No insects were found on Russian-olive, the fifth most prevalent tree.

Key word: insects, shelterbelts, North Dakota

Kennedy, Patrick C., and Wilson, Louis F.
1969. Major insect pests in North Dakota shelterbelts: abundance and distribution by climate and host age. U.S.D.A. Forest Service Research Paper RM-47, 12 pp., illus. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado 80521.

Over 30 species of insects and mites were found on 23 species of trees and shrubs. A prevalence index was devised to compare relative numbers of insects and their impact on hosts. The caragana blister beetle, woolly elm aphid, boxelder twig borer, poplar petiole gall aphid, fall cankerworm, and spur-throated grasshopper had highest prevalence indices. No insects were found on Russian-olive, the fifth most prevalent tree.

Key words: insects, shelterbelts, North Dakota

Kennedy, Patrick C., and Wilson, Louis F.
1969. Major insect pests in North Dakota shelterbelts: abundance and distribution by climate and host age. U.S.D.A. Forest Service Research Paper RM-47, 12 pp., illus. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado 80521.

Over 30 species of insects and mites were found on 23 species of trees and shrubs. A prevalence index was devised to compare relative numbers of insects and their impact on hosts. The caragana blister beetle, woolly elm aphid, boxelder twig borer, poplar petiole gall aphid, fall cankerworm, and spur-throated grasshopper had highest prevalence indices. No insects were found on Russian-olive, the fifth most prevalent tree.

Key word: insects, shelterbelts, North Dakota

Kennedy, Patrick C., and Wilson, Louis F.
1969. Major insect pests in North Dakota shelterbelts: abundance and distribution by climate and host age. U.S.D.A. Forest Service Research Paper RM-47, 12 pp., illus. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado 80521.

Over 30 species of insects and mites were found on 23 species of trees and shrubs. A prevalence index was devised to compare relative numbers of insects and their impact on hosts. The caragana blister beetle, woolly elm aphid, boxelder twig borer, poplar petiole gall aphid, fall cankerworm, and spur-throated grasshopper had highest prevalence indices. No insects were found on Russian-olive, the fifth most prevalent tree.

Key words: insects, shetlerbelts, North Dakota

About The Forest Service. . . .

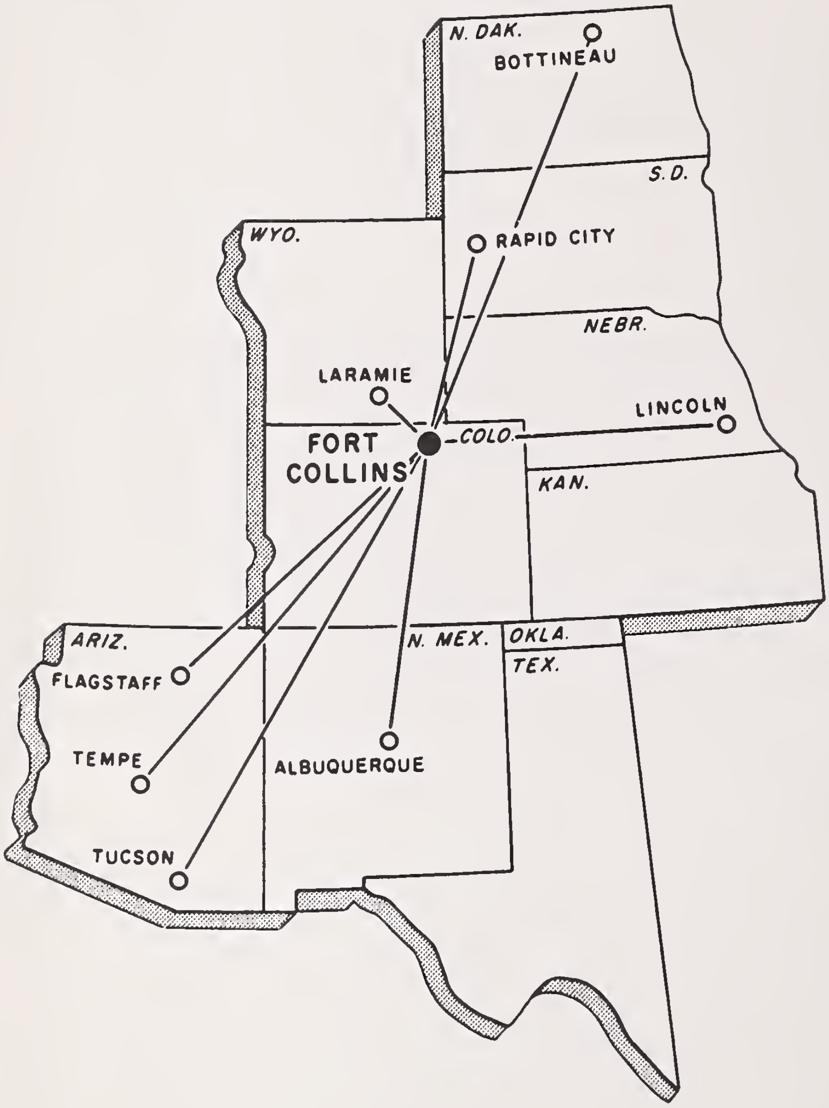
As our Nation grows, people expect and need more from their forests—more wood; more water, fish and wildlife; more recreation and natural beauty; more special forest products and forage. The Forest Service of the U. S. Department of Agriculture helps to fulfill these expectations and needs through three major activities:

- Conducting forest and range research at over 75 locations ranging from Puerto Rico to Alaska to Hawaii.
- Participating with all State forestry agencies in cooperative programs to protect, improve, and wisely use our Country's 395 million acres of State, local, and private forest lands.
- Managing and protecting the 187-million acre National Forest System.

The Forest Service does this by encouraging use of the new knowledge that research scientists develop; by setting an example in managing, under sustained yield, the National Forests and Grasslands for multiple use purposes; and by cooperating with all States and with private citizens in their efforts to achieve better management, protection, and use of forest resources.

Traditionally, Forest Service people have been active members of the communities and towns in which they live and work. They strive to secure for all, continuous benefits from the Country's forest resources.

For more than 60 years, the Forest Service has been serving the Nation as a leading natural resource conservation agency.



N. DAK.
BOTTINEAU
S. D.
RAPID CITY
WYO.
NEBR.
LARAMIE
LINCOLN
FORT COLLINS
COLO.
KAN.
ARIZ.
N. MEX.
OKLA.
TEX.
FLAGSTAFF
TEMPE
ALBUQUERQUE
TUCSON